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## Discharge and Treatment of Waste Water in Denmark

*a case study about Esbjerg*

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*Published in:*  
Proceedings of Water Services Association Workshop

*Publication date:*  
1990

*Document Version*  
Accepted author manuscript, peer reviewed version

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*  
Larsen, T. (1990). Discharge and Treatment of Waste Water in Denmark: a case study about Esbjerg. In *Proceedings of Water Services Association Workshop: on the proposed EC directive concerning municipal waste water treatment* (pp. 8-17).

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Proceedings of  
Water Services Association Workshop  
on the proposed EC directive concerning  
municipal waste water treatment

London, 3 - 4 May 1990

## COUNTRY SITUATION PAPER: DENMARK

### DISCHARGE AND TREATMENT OF WASTE WATER IN DENMARK; A CASE STORY ABOUT ESBJERG

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#### SYNOPSIS

This paper describes the waste water treatment situation in the area of Esbjerg. This example was chosen because the situation in Esbjerg is typical of that of most towns in Denmark, and because Esbjerg is closest to the British situation with respect to the receiving water.

Esbjerg has a population of 70 000 inhabitants, and waste water treatment takes place in two treatment plants. These plants are now being extended to perform tertiary treatment, to fulfil the new Danish requirements. From 1992, the maximum average concentrations allowed for municipal waste water discharges to receiving waters will be: 15 mg/l for BOD<sub>5</sub>, 8 mg/l for total nitrogen, and 1.5 mg/l for total phosphorus. These general requirements cover all types of receiving waters, but regional authorities have, in a number of cases, fixed lower values for sensitive areas.

The paper below was written by Nellemann, consulting engineers and planners, Aalborg, who kindly gave their permission for its presentation at the workshop.

#### INTRODUCTION

In accordance with the Danish Act on Environmental Protection, the municipality of Esbjerg has developed a so-called 'sewage plan'. This sewage plan forms the basis for all waste water treatment plants until 1992.

In connection with the development of the plan, considerable planning and investigation were needed, in order to ensure that the necessary construction activities would be carried out on the basis of a well-documented continuous and goal-directed plan, which was justifiable from the environmental, technical, and economic viewpoints.

Implementation of the sewage plan was started in 1986 with the extension of the two central purification plants in Esbjerg. In the period from 1986 to 1993, 400 to 500 million DKR will be invested in this project.

#### BASIS OF IDEAS

The basis for the sewage plan is pre-purification at the source of pollution, taking into consideration regional demands regarding the quality of the receiving water. To encourage this, the



municipality of Esbjerg adopted a new set of payment regulations in 1986, which will have economic consequences primarily for the most polluting companies, based on the 'polluter pays' principle.

In Denmark, sewage treatment is a municipal service, but the more stringent demands regarding waste water necessitate greater effort from the users of the service. This includes control of industrial production and adaptation of drainage facilities, so that heavy stresses on the treatment plants are avoided, for example, by minimizing variations in the amount and characteristics of the waste water.

The increase in the costs for discharging in relation to the degree of pollution from industries contributes to the fulfilment of the targets.

#### THE CENTRAL TREATMENT PLANTS

Waste water treatment in Esbjerg takes place in two central purification plants, one located in the western part of the town and the other located in the eastern part. A map of the area showing the locations of the treatment plants and the amounts of pollution dealt with (in population equivalents, p.e.) is shown in Fig. 1.

#### DIMENSIONING

##### Existing Environmental Impact

Table 1 shows the average loads on the two waste water treatment plants in Esbjerg in 1986 and 1987.

TABLE 1 Average Loads on Waste Water Treatment Plants in Esbjerg

Treatment plant	Year	Waste water volume, million m <sup>3</sup> /year	Organic load*, p.e.	Maximum load, p.e./day
East	1986	4.6	88 000	
	1987	5.0	103 000	240 000
West	1986	10.0	230 000	
	1987	11.5	275 000	540 000
TOTAL	1986	14.6	318 000	
	1987	16.5	378 000	780 000

\*average daily organic pollution load over the year

The waste water originates from both households and industry, with domestic waste water amounting to about 75 000 p.e. and 305 000 p.e. coming from industry.

##### Future Environmental Impact

The future treatment plant capacity needed is based on consideration of the degree of freedom required by the municipality of Esbjerg concerning new enterprises and housing areas.

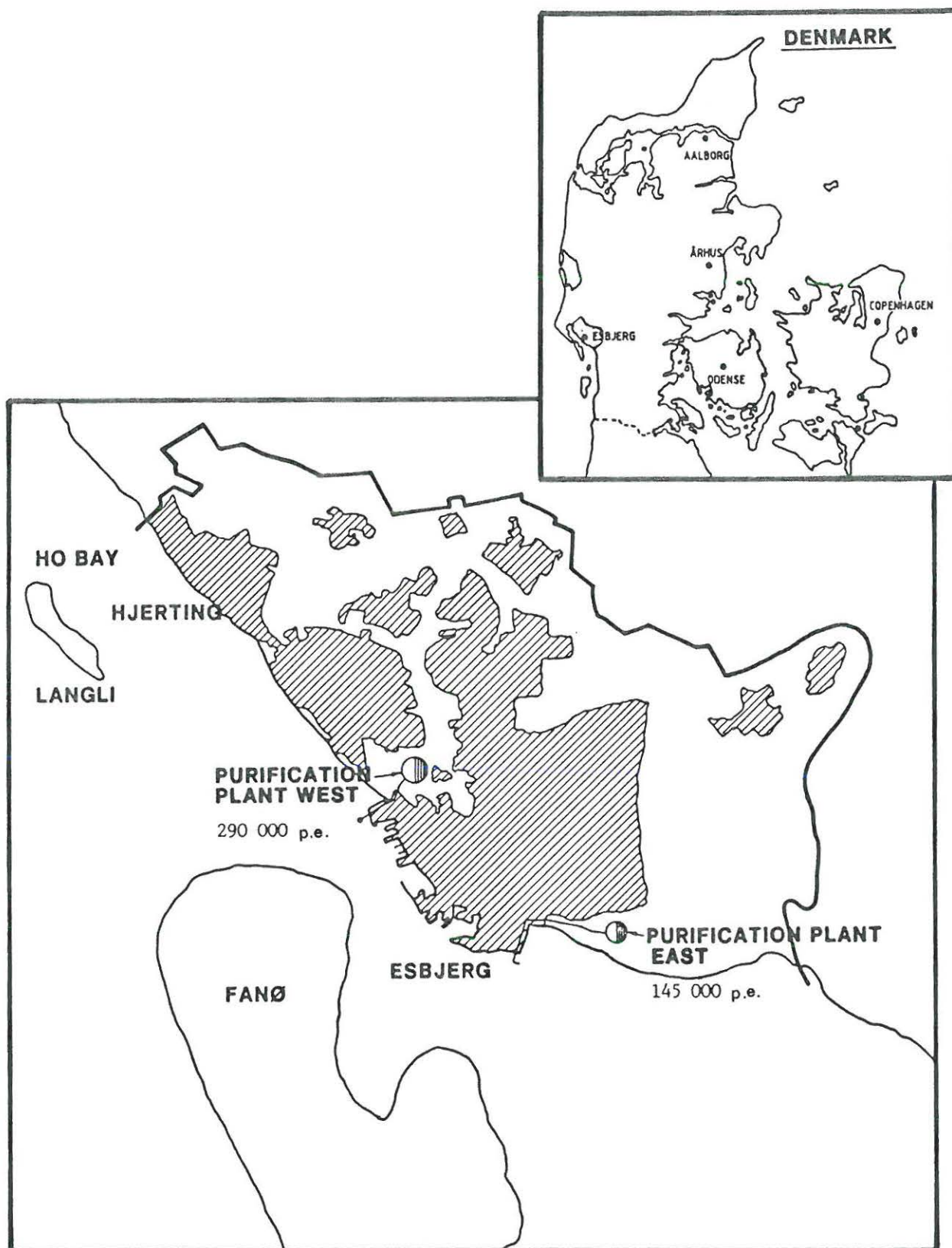


Fig. 1. The municipality of Esbjerg, showing the locations of the waste water treatment plants

The 'West' Treatment Plant will be extended to a capacity of 290 000 p.e. and the 'East' Plant to a capacity of 145 000 p.e.



The amount of treatment capacity used by households and industry, and the spare capacity, will be as follows: households 75 000 p.e.; industry 165 000 p.e.; and, spare capacity 205 000 p.e. It can be seen that the spare capacity comes almost entirely from the reduction of the load from the polluting industries.

#### Expansion of the West Treatment Plant

The capacity of the West Treatment Plant has been extended to 290 000 p.e., and the basis for dimensioning of the plant is shown in Table 2.

TABLE 2 Data for Dimensioning of West Treatment Plant

<u>Water Quantities</u>		
Dry weather:	24 hours average, m <sup>3</sup>	35 000
	maximum hourly flow rate, m <sup>3</sup> /h	2 340
Rain:	to sand trap, maximum hourly rate, m <sup>3</sup> /h	9 360
	to chemical precipitation, m <sup>3</sup> /h	4 680
<u>Pollution</u>		
	BOD <sub>5</sub> , 24 hours, kg	17 500
	COD, 24 hours, kg	33 000
	SS, 24 hours, kg	13 000
	Total P, 24 hours, kg	675
	Total N, 24 hours, kg	2 300

#### Expansion of the East Treatment Plant

The capacity of the East Treatment Plant has been extended to 145 000 p.e., and the basis for dimensioning of the plant is shown in Table 3.

TABLE 3 Data for Dimensioning of East Treatment Plant

<u>Water Quantities</u>		
Dry weather:	24 hours average, m <sup>3</sup>	19 000
	maximum hourly flow rate, m <sup>3</sup> /h	1 350
Rain:	to sand trap, maximum hourly rate, m <sup>3</sup> /h	5 400
	to chemical precipitation, m <sup>3</sup> /h	2 700
<u>Pollution</u>		
	BOD <sub>5</sub> , 24 hours, kg	9 500
	COD, 24 hours, kg	17 100
	SS, 24 hours, kg	7 220
	Total P, 24 hours, kg	1 520
	Total N, 24 hours, kg	380

#### Energy Balance

The gas produced in the digesters of the treatment plants is used for the production of electricity and for heating by burning it in a gas generator plant.

An energy balance for the West Treatment Plant for the first stage looks as follows:

- |   |                    |
|---|--------------------|
| - Demand for electricity (per 24 hours):          | 3 120 kWh          |
| - Demand for heating (per 24 hours):              | 7 000 to 9 800 kWh |
| - Gas production, 4 200 m <sup>3</sup> /24 hours: | 26 800 kWh         |
| - Heat production:                                | 12 600 kWh         |
| - Electricity production:                         | 6 300 kWh          |

It can be seen that the plant is self-sufficient with respect to energy over an average 24 hour period. However, after the start of the second stage, the demand for electricity will greatly exceed the quantity of energy produced.

## FUNCTIONING OF THE TREATMENT PLANTS

### Choice of Method

During the development of the sewage plan in 1984, it was decided that expansion of the East and/or West treatment plants was the best option. This choice was made based partly on considerations concerning the composition of the waste water and variations in the amounts of substances, and partly due to the fact that the expansion takes place in stages, since the demands regarding sewage treatment had not at that time been finally decided.

The main features of the expansion programme were:

- increased efficiency of mechanical purification;
- addition of chemical precipitation;
- addition of biological purification, including removal of nitrogen.

In 1985, large-scale experiments were conducted with chemical precipitation, in order to establish the levels of treatment possible with a variety of chemicals. Precipitation with iron chloride is in full-scale use at the East Treatment Plant.

In 1986, a master plan for the West Treatment Plant was developed, in which the economic consequences of various alternative plant configurations were investigated. In 1987, a similar master plan was developed for the East Treatment Plant.

At the same time, a project proposal for the first stage of the West Treatment Plant was developed, which included mechanical and biological purification. The project proposal stipulated the size of the construction and thus detailed forecasts could be made and the work started.

In 1988, an experimental plant for biological purification, including the removal of nitrogen, was constructed. The results from this experimental plant were intended to form the basis of the development of the project proposal for the second stage of the West Treatment Plant, which includes biological purification with removal of nitrogen.



## Discharge Standards

In May 1987, the Danish Parliament passed the 'Aquatic Environment Plan', which stipulates that discharges from public waste water treatment plants must be reduced to: BOD<sub>5</sub> (organic compounds) < 15.0 mg/l; total nitrogen < 8.0 mg/l; and, total phosphorus < 1.5 mg/l. After negotiations with the National Agency of Environmental Protection, it was agreed that these demands are to be complied with before 1992 and 1993 for the West and East Treatment Plants, respectively. These discharge standards mean that greater than 90% purification efficiency must be achieved.

## Process Configurations

Figures 2 and 3 show how this purification efficiency can be obtained by means of mechanical, chemical, and biological processes. These figures illustrate the functions of the various elements of the plant. Figure 4 illustrates how the sludge, which is the main residual of the treatment processes, is treated.

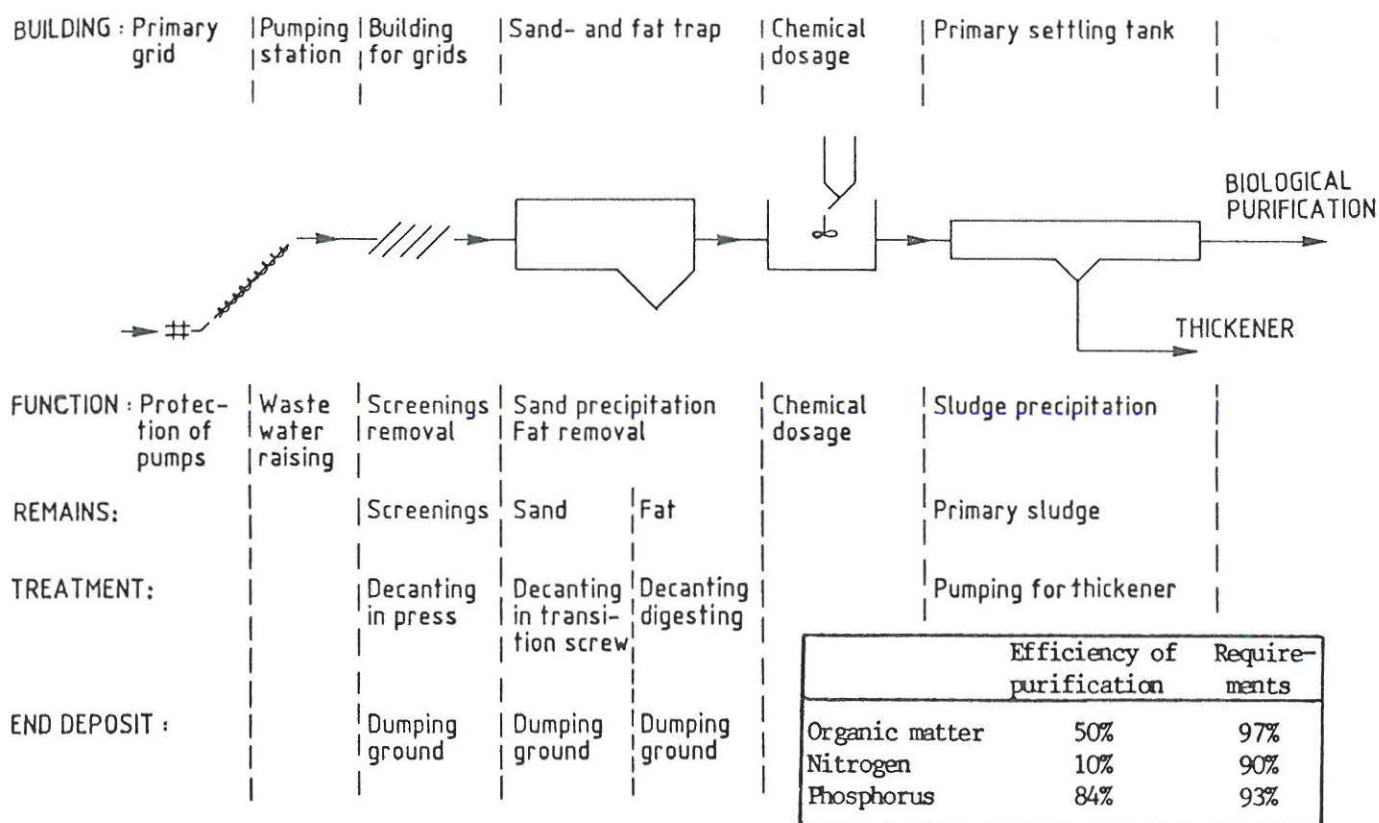


Fig. 2. Diagram of mechanical-chemical treatment scheme with description of the function of each stage

## TIME AND ACTIVITY SCHEDULES

The expansion of the treatment plants should be completed in 1992. The plants are being augmented in two sections, the first section comprising mechanical-chemical treatment, and the second section comprising biological treatment with removal of nitrogen. During 1986-87, new pumping stations and outlet pipelines with advanced diffuser arrangements were constructed.



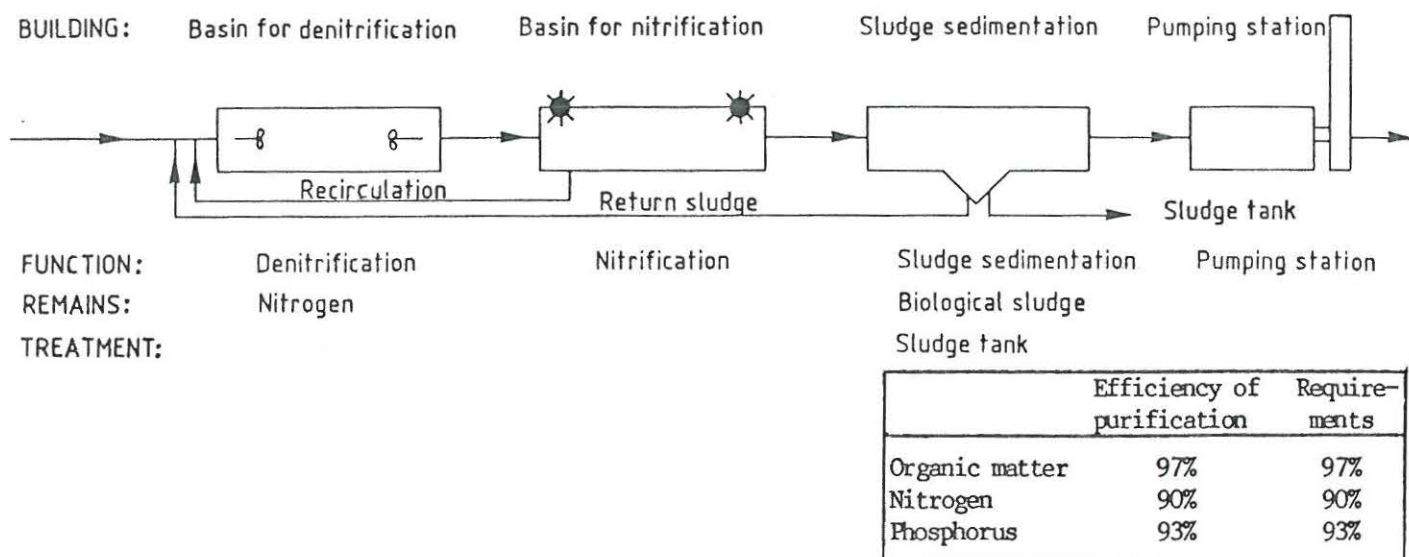


Fig. 3. Diagram of biological treatment scheme with description of the function of each stage

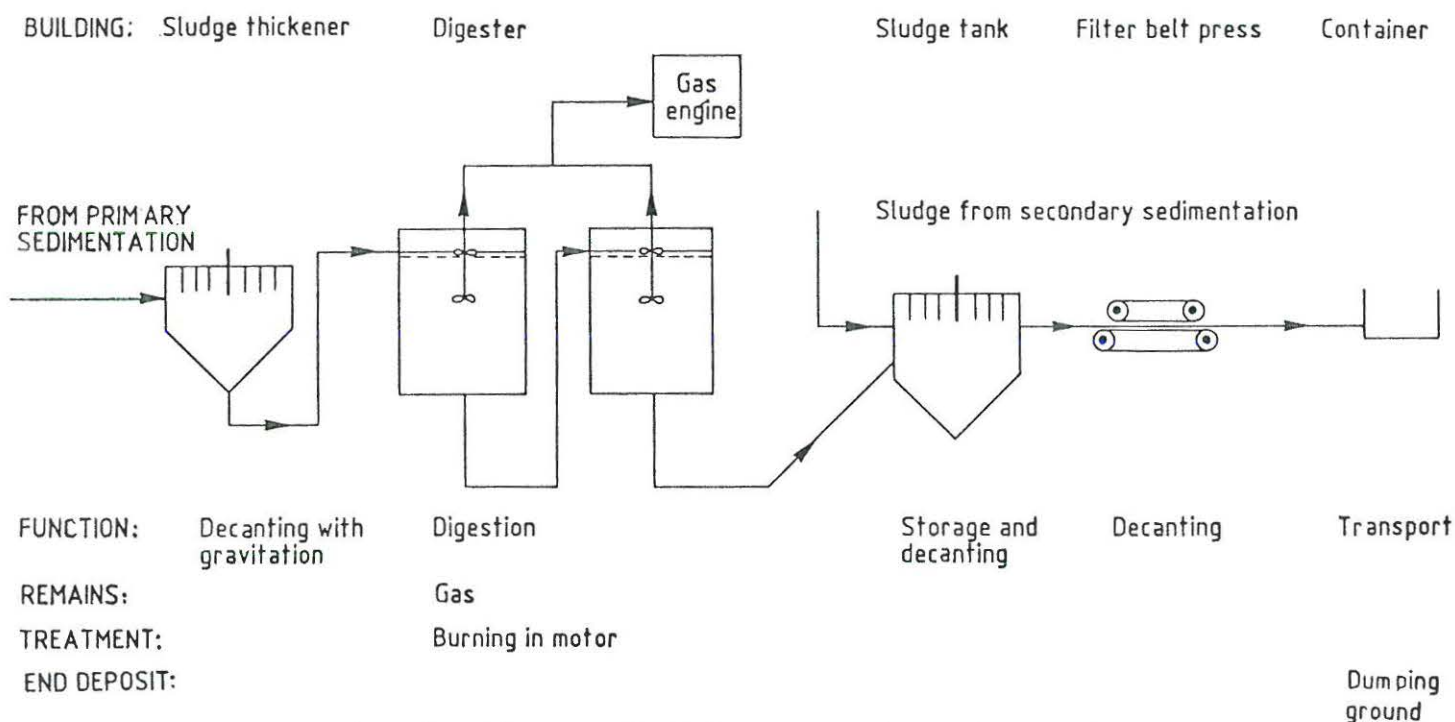


Fig. 4. Diagram of sludge processing scheme with description of the function of each stage

The first section includes the following installations:

- new screw pumping station with three identical screws;
- new grid house with two archgrids, screening press, and electromagnetic flow measuring instruments;
- new sand and grease trap, constructed as two parallel sand and grease traps. Sand dewaterer, grease trap, and containers are to be installed;

- new chemical entrainment plan for entrainment of iron chlorides, calcium, and polymer;
- new primary tank which functions as a primary tank in dry weather and a rain water relief tank during rainy weather. The tank is constructed with a built-in flocculation chamber. The existing primary tank is to be altered in accordance with the above-mentioned principles and the concrete surfaces restored;
- four new tanks for concentration of primary sludge before pumping into digesters;
- two new digesters for digestion of sludge are to be erected. Two existing digesters are to be altered with new stirrers and new fronts;
- a new boiler house is to be built near the four digesters. This will increase the existing boiler and gas turbine capacities;
- two new sludge storage areas are to be constructed, for storage of digested sludge before sludge dewatering.

Immediately after completion of the first construction stage of the two plants, the second stage will be initiated. This comprises nitrification and denitrification tanks, sludge sedimentation tanks, intermediary pumping station, compriming machine, and sludge dewatering plant.

#### COSTS

Table 4 shows the investment costs for the Esbjerg East and West Treatment Plants, for the period 1986 to 1992.

TABLE 4 Treatment Plant Investment Costs (Total Costs in Million DKR)

	1986	1987	1988	1989	1990	1991	1992	TOTAL
<u>Esbjerg West Treatment Plant</u>								
Mechanical-chemical treatment	0.8	10.4	57.3	32.3	0	0	0	100.8
Biological treatment	0	0	0	33.5	42.3	46.2	0	122.0
<u>Esbjerg East Treatment Plant</u>								
Mechanical-chemical treatment	0.4	1.4	15.5	44.8	3.9	0	0	66.0
Biological treatment	0	0	0	0	20.4	30.3	30.3	81.0
<b>TOTAL</b>	<b>1.2</b>	<b>11.8</b>	<b>72.8</b>	<b>110.6</b>	<b>66.6</b>	<b>76.5</b>	<b>30.3</b>	<b>369.8</b>

#### SEA OUTFALLS

In 1986/87, new pumping stations and outfall pipelines were constructed for the East and West treatment plants.

### Outfall Pipeline from the West Treatment Plant

Waste water from the West Treatment Plant is pumped through a one-metre diameter outfall pipeline to an outfall system in the territorial seawater with a diffuser at 9 m depth (see Figs 5 and 6). The pipeline is 1800 m long and it has a capacity of 1300 l/s.

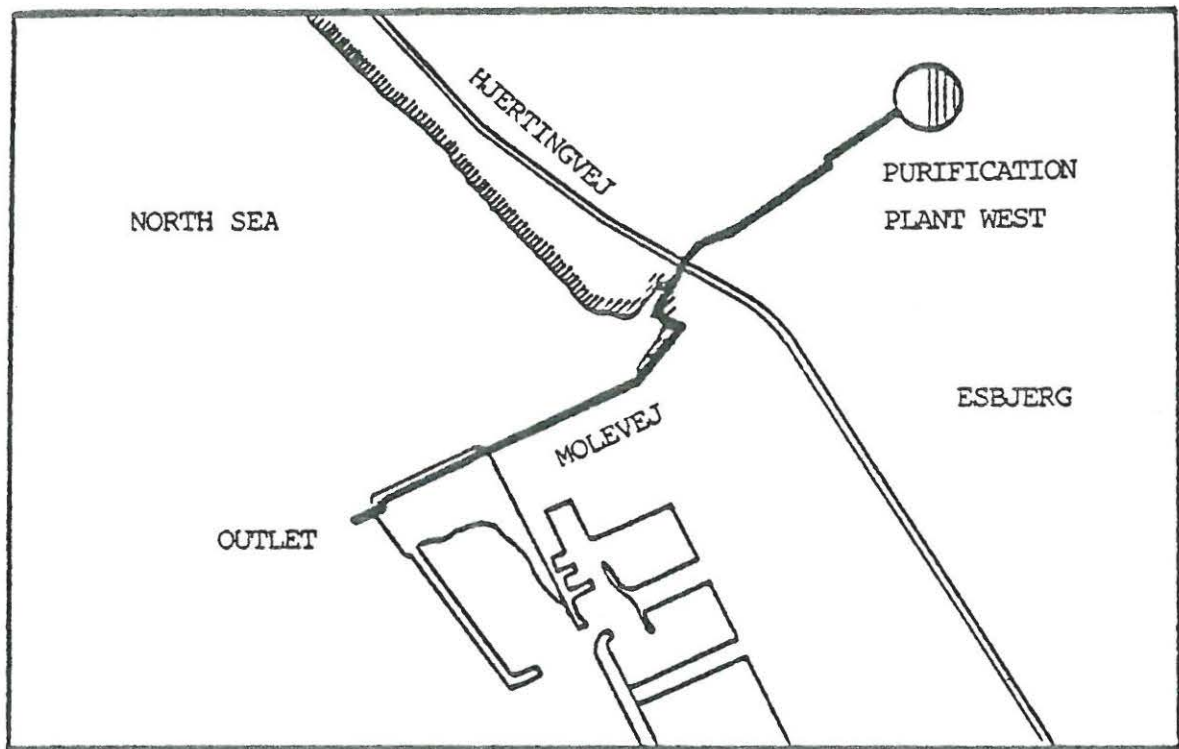


Fig. 5. Map showing the outfall pipeline from the West Treatment Plant

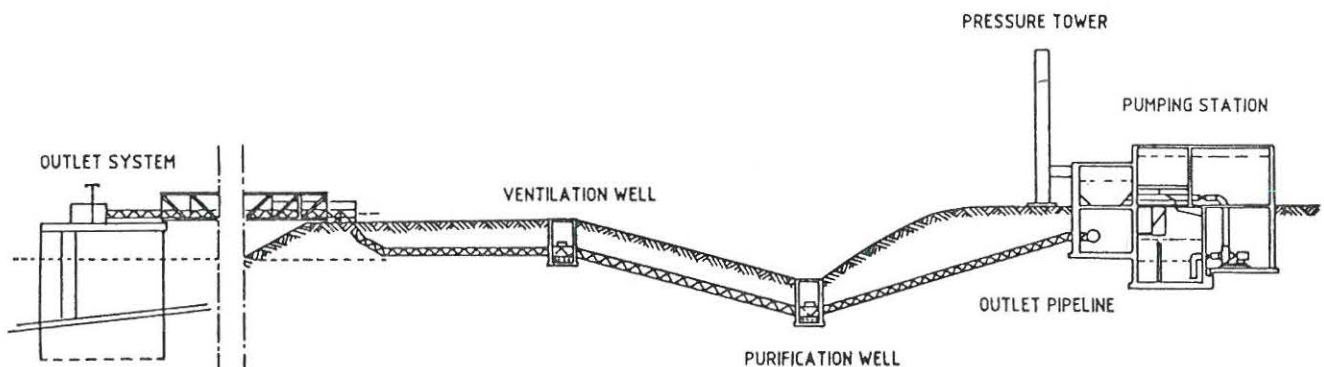


Fig. 6. Diagram of the outfall pipeline from the West Treatment Plant

A one-metre diameter pipeline for cooling and deodorising water from some fishmeal factories has been constructed parallel with the last 300 m of the outfall pipeline. The capacity of this pipeline is 1800 l/s. A pumping station has been constructed to pump the discharges into Ho Bay through a diffuser. The two pipelines have a common sheet piled outlet island with an outlet chamber and diffuser. The outfall pipelines and other works were constructed in 1986/87.



### Outfall Pipeline from the East Treatment Plant

Waste water from the East Treatment Plant is pumped through an 800-mm diameter outfall pipeline to an outfall system with a diffuser at 7 m depth in a quay frame in the southern extension of Esbjerg Harbour (see Fig. 7). The pipeline is 2800 m long and it has a capacity of 800 l/s. The pumping station and pressure tower were constructed at the treatment plant, and the whole outfall system was built in 1986/87.

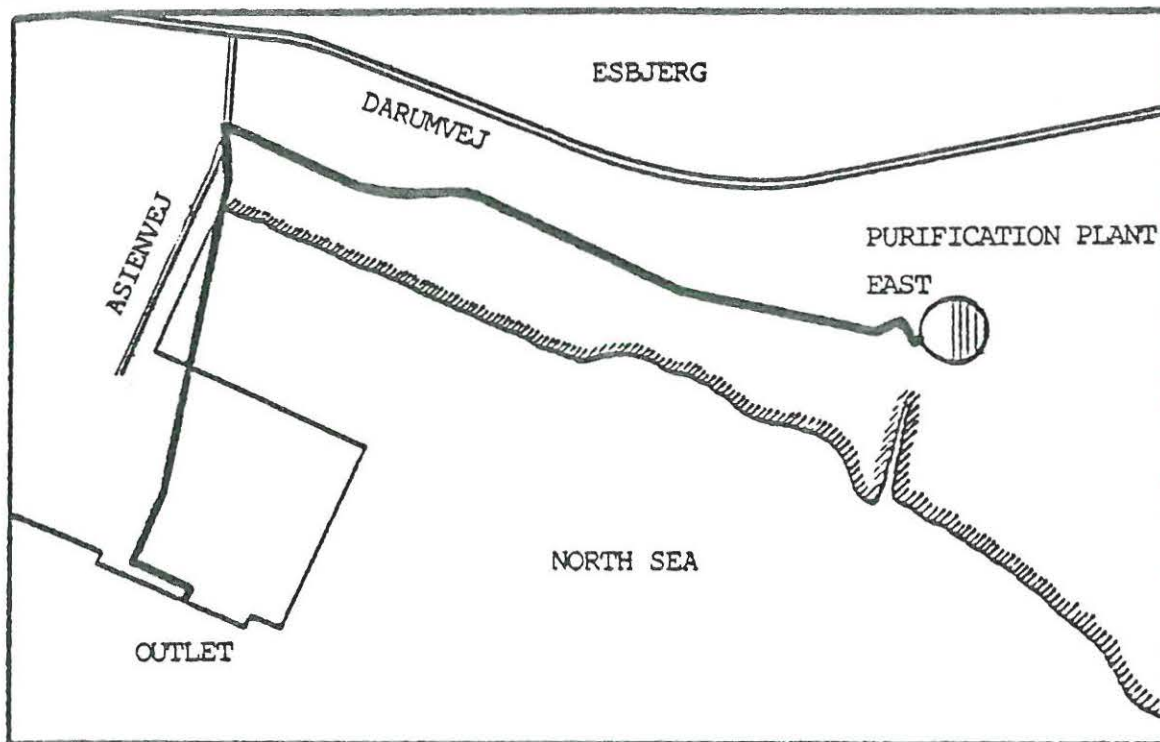


Fig. 7. Map showing the outfall pipeline from the East Treatment Plant

### COUNTRY SITUATION PAPER: FRANCE

#### WASTE WATER TREATMENT IN FRANCE

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#### INTRODUCTION

In France, the mayors of the 36 000 'communes' (towns and villages) and their various associations are the decision-makers regarding sewerage systems. Therefore, there are no reliable